CLAIMS

What is claimed is:

1. A method for reducing motion-related artifacts in a CT image, comprising:

acquiring a projection data set during one or more slow rotations or a partial rotation of a CT gantry about a dynamic object;

determining one or more motion data sets representing the motion of the dynamic object over time from the projection data set or from two or more images reconstructed from the projection data set; and

reconstructing one or more motion-corrected images of the object using one or more projections from the projection data set and the respective motion data set corresponding to the one or more projections.

2. The method as recited in claim 1, wherein the dynamic object is a heart.

3. The method as recited in claim 1, wherein reconstructing the one or more motion-corrected images comprises warping a reconstruction grid at a view angle in accordance with the motion data set for the view angle and backprojecting the projections corresponding to the view angle onto the warped reconstruction grid.

4. The method as recited in claim 1, wherein the projection data set is acquired during one slow rotation of the CT gantry.

5. The method as recited in claim 1, wherein the one or more slow rotations or the partial rotation take at least ten seconds per rotation.

6. The method as recited in claim 1, wherein the one or more slow rotations or the partial rotation take approximately fifteen seconds per rotation.

7. A method for reducing motion-related artifacts in a CT cardiac image, comprising:

acquiring a projection data set during one or more slow rotations or a partial rotation of a CT gantry about a heart, wherein the projection data set comprises a plurality of projections;

acquiring a phase data set for the heart from at least one of an ECG data set, an ultrasound image data set, a tagged MRI data set, and the projection data set;

determining cardiac motion from the projection data set and the phase data set or from one or more images generated from the projection data set and the phase data set;

warping one or more reconstruction grids based upon the determined cardiac motion, wherein each reconstruction grid is associated with a view angle; and

backprojecting a corresponding projection onto a respective warped reconstruction grid for all view angles to generate a motion corrected image, wherein the corresponding projection comprises the projection acquired at the respective view angle associated with the warped reconstruction grid.

8. The method as recited in claim 7, further comprising associating the motion-corrected images spatially, temporally, or spatially and temporally.

9. The method as recited in claim 7, wherein the projection data set is acquired during one slow rotation of the CT gantry.

10. The method as recited in claim 7, wherein the one or more slow rotations or the partial rotation take at least ten seconds per rotation.

11. The method as recited in claim 7, wherein the one or more slow rotations or the partial rotation take approximately fifteen seconds per rotation.

12. The method as recited in claim 7, wherein the phase data set is acquired from consistency condition moments of the projection data set.

13. The method as recited in claim 7, wherein determining cardiac motion, comprises:

reconstructing a phase-specific image for each phase of interest from a weighted projection set for the phase of interest, wherein the weighted projection set comprises the projection data set with projections corresponding to the phase of interest weighted higher; and

determining motion between temporally adjacent phase-specific images.

14. The method as recited in claim 13, wherein the phase-specific image is reconstructed iteratively.

15. The method as recited in claim 14, wherein iteratively reconstructing the phase-specific image uses a non-time resolved reconstruction to facilitate iterative computation of one or more temporally varying regions in the phase-specific image.

16. The method as recited in claim 7, wherein determining cardiac motion, comprises:

reconstructing two or more time-resolved images using the projection data set and the phase data set; and

correlating the location of one or more regions of interest in the two or more time-resolved images to generate a respective image displacement map for each pair of time-resolved images.

17. The method as recited in claim16, further comprising:

determining whether the correlation of the locations of the regions of interest exceeds a correlation threshold for each image displacement map; and

subdividing the region of interest and updating the displacement maps until the correlation threshold is exceeded.

18. The method as recited in claim 7, wherein determining cardiac motion, comprises:

reconstructing two or more phase-specific images using the projection data set and the phase data set;

decomposing one or more regions of interest in the two or more phase-specific images to generate wavelet coefficients of the regions of interest; and

analyzing the differences between the wavelet coefficients to generate a respective image displacement map for each pair of time-resolved images.

19. The method as recited in claim 18, further comprising:

determining whether the correlation of the wavelet coefficients of the regions of interest exceeds a correlation threshold for each image displacement map; and

subdividing the region of interest and updating the displacement maps until the correlation threshold is exceeded.

20. The method as recited in claim 7, wherein determining cardiac motion, comprises:

reconstructing a time-resolved image at the phase of minimum motion using the projection data set and the phase data set;

identifying one or more view angles associated with the next adjacent phase;

forward-projecting the time-resolved image at the identified view angles to generate a set of forward projected data;

minimizing the difference between the forward projected data and the projection data set to generate a set of phase-specific displacement data;

reconstructing a phase-specific image at the next phase using the phase-specific displacement data; and

generating a set of phase-specific displacement data for the phase-specific image at the next phase and for the remaining phases of interest.

21. The method as recited in claim 7, wherein determining cardiac motion comprises:

identifying one or more view angles corresponding to a cardiac phase;

subtracting the projection data acquired at the next adjacent views from the projection data acquired at the view angles to generate one or more respective differential signals for the cardiac phase; and

generating motion data from the one or more respective differential signals for the remaining phases of interest.

22. A computer program, provided on one or more computer readable media, for reducing motion-related artifacts in a CT image, comprising:

a routine for acquiring a projection data set during one or more slow rotations or a partial rotation of a CT gantry about a dynamic object;

a routine for determining one or more motion data sets representing the motion of the dynamic object over time from the projection data set or from two or more images reconstructed from the projection data set; and

a routine for reconstructing one or more motion-corrected images of the object using one or more projections from the projection data set and the respective motion data corresponding to the one or more projections.

23. The computer program as recited in claim 22, wherein the dynamic object is a heart.

24. The computer program as recited in claim 22, wherein the routine for reconstructing the one or more motion-corrected images warps a reconstruction grid at a view angle in accordance with the motion data for the view angle and backprojects the projections corresponding to the view angle onto the warped reconstruction grid.

25. A computer program, provided on one or more computer readable media, for reducing motion-related artifacts in a CT cardiac image, comprising:

a routine for acquiring a projection data set during one or more slow rotations or a partial rotation of a CT gantry about a heart, wherein the projection data set comprises a plurality of projections;

a routine for acquiring a phase data set for the heart from at least one of an ECG data set, an ultrasound image data set, a tagged MRI data set, and the projection data set;

a routine for determining cardiac motion from the projection data set and the phase data set or from one or more images generated from the projection data set and the phase data set;

a routine for warping one or more reconstruction grids based upon the determined cardiac motion, wherein each reconstruction grid is associated with a view angle; and

a routine for backprojecting a corresponding projection onto a respective warped reconstruction grid for all view angles to generate a motion corrected image, wherein the corresponding projection comprises the projection acquired at the respective view angle associated with the warped reconstruction grid.

26. The computer program as recited in claim 25, further comprising a routine for associating the motion-corrected images spatially, temporally, or spatially and temporally.

27. The computer program as recited in claim 25, wherein the phase data set is acquired from consistency condition moments of the projection data set.

28. The computer program as recited in claim 25, wherein the routine for determining cardiac motion reconstructs a phase-specific image for each phase of interest from a weighted projection set, wherein the weighted projection set comprises the projection data set with projections corresponding to the phase of interest weighted higher, and determines motion between temporally adjacent phase-specific images.

29. The computer program as recited in claim 28, wherein the routine for determining cardiac motion reconstructs the phase-specific image iteratively.

30. The computer program as recited in claim 29, wherein the routine for determining cardiac motion uses a non-time resolved reconstruction to facilitate iterative computation of one or more temporally varying regions in the phase-specific image.

31. The computer program as recited in claim 25, wherein the routine for determining cardiac motion reconstructs two or more time-resolved images using the projection data set and the phase data set and correlates the location of one or more regions of interest in the two or more time-resolved images to generate a respective image displacement map for each pair of time-resolved images.

32. The computer program as recited in claim 31, wherein the routine for determining cardiac motion determines whether the correlation of the locations of the regions of interest exceeds a correlation threshold for each image displacement map and subdivides the region of interest and updates the displacement maps until the correlation threshold is exceeded.

33. The computer program as recited in claim 25, wherein the routine for determining cardiac motion reconstructs two or more phase-specific images using the projection data set and the phase data set, decomposes one or more regions of interest in the two or more phase-specific images to generate wavelet coefficients of the regions of interest, and analyzes the differences between the wavelet coefficients to generate a respective image displacement map for each pair of time-resolved images.

34. The computer program as recited in claim 33, wherein the routine for determining cardiac motion determines whether the correlation of the wavelet coefficients of the regions of interest exceeds a correlation threshold for each image displacement map, and subdivides the region of interest and updates the displacement maps until the correlation threshold is exceeded.

35. The computer program as recited in claim 25, wherein the routine for determining cardiac motion reconstructs a time-resolved image at the phase of minimum motion using the projection data set and the phase data set, identifies one or more view angles associated with the next adjacent phase, forward-projects the time-resolved image at the identified view angles to generate a set of forward projected data, minimizes the difference between the forward projected data and the projection data set to generate a set of phase-specific displacement data, reconstructs a phase-specific image at the next phase using the phase-specific displacement data; and generates a set of phase-specific displacement data for the phase-specific image at the next phase and for the remaining phases of interest.

36. The computer program as recited in claim 25, wherein the routine for determining cardiac motion identifies one or more view angles corresponding to a cardiac phase, subtracts the projection data acquired at the next adjacent views from the respective projection data acquired at the view angles to generate one or more respective differential signals for the cardiac phase, and generates motion data from the one or more respective differential signals for the remaining phases of interest.

37. A CT image analysis system, comprising:

a gantry comprising an X-ray source configured to emit a stream of radiation, wherein the gantry rotates slowly;

a detector configured to detect the stream of radiation and to generate one or more signals responsive to the stream of radiation, wherein the detector comprises a plurality of detector elements;

a system controller configured to control the X-ray source and to acquire a set of projection data during one or more slow rotations or a partial rotation of the X-ray source about a dynamic object from one or more of the detector elements via a data acquisition system; and

a computer system configured to receive the set of projection data, to determine one or more motion data sets representing the motion of the dynamic object over time from the set of projection data or from two or more images reconstructed from

the set of projection data, and to reconstruct one or more motion-corrected images of the object using one or more projections from the set of projection data and the respective motion data corresponding to the one or more projections.

38. The CT image analysis system, as recited in claim 37, wherein the dynamic object is a heart.

39. The CT image analysis system, as recited in claim 37, wherein the computer is configured to reconstruct one or more motion-corrected images by warping a reconstruction grid at a view angle in accordance with the motion data for the view angle and backprojecting the projections corresponding to the view angles onto the respective warped reconstruction grids.

40. The CT image analysis system, as recited in claim 37, wherein the one or more slow rotations or the partial rotation of the gantry take at least ten seconds per rotation.

41. The CT image analysis system, as recited in claim 37, wherein the one or more slow rotations or the partial rotation of the gantry take approximately 15 seconds.

42. A CT image analysis system, comprising:

a gantry comprising an X-ray source configured to emit a stream of radiation, wherein the gantry rotates slowly;

a detector configured to detect the stream of radiation and to generate one or more signals responsive to the stream of radiation, wherein the detector comprises a plurality of detector elements;

a system controller configured to control the X-ray source and to acquire a set of projection data during one or more slow rotations or a partial rotation of the X-ray source about a heart from one or more of the detector elements via a data acquisition system, wherein the set of projection data comprises a plurality of projections; and

a computer system configured to receive the set of projection data, to acquire a phase data set for the heart from at least one of an ECG data set, an ultrasound image data set, a tagged MRI data set, and the projection data set, to determine cardiac motion from the projection data set and the phase data set or from one or more images generated from the projection data set and the phase data set, to warp one or more reconstruction grids based upon the determined cardiac motion, wherein each reconstruction grid is associated with a view angle, and to backproject a corresponding projection onto a respective warped reconstruction grid for all view angles to generate a motion corrected image, wherein the corresponding projection comprises the projection acquired at the respective view angle associated with the warped reconstruction grid.

43. A CT image analysis system as recited in claim 42, wherein the computer is further configured to associate the motion-corrected images spatially, temporally, or spatially and temporally.

44. A CT image analysis system as recited in claim 42, wherein the set of projection data is acquired during one slow rotation of the X-ray source.

45. The CT image analysis system, as recited in claim 42, wherein the one or more slow rotations or the partial rotation of the gantry take at least ten seconds per rotation.

46. The CT image analysis system, as recited in claim 42, wherein the one or more slow rotations or the partial rotation of the gantry take approximately 15 seconds.

47. The CT image analysis system, as recited in claim 42, wherein the computer is configured to determine cardiac motion by reconstructing a phase-specific image for each phase of interest from a weighted projection set for the phase of interest, wherein the weighted projection set comprises the projection data set with projections corresponding to the phase of interest weighted higher and by determining motion between temporally adjacent phase-specific images.

48. The CT image analysis system, as recited in claim 45, wherein the computer is configured to reconstruct the phase-specific images iteratively.

49. The CT image analysis system, as recited in claim 48, wherein the computer is further configured to reconstruct the phase-specific images using a non-time resolved reconstruction to facilitate iterative computation of one or more temporally varying regions in the phase-specific image.

50. The CT image analysis system, as recited in claim 42, wherein the computer is configured to determine cardiac motion by reconstructing two or more time-resolved images using the projection data set and the phase data set and by correlating the location of one or more regions of interest in the two or more time-resolved images to generate a respective image displacement map for each pair of time-resolved images.

51. The CT image analysis system, as recited in claim 50, wherein the computer is further configured to determine whether the correlation of the locations of the regions of interest exceeds a correlation threshold for each image displacement map and to subdivide the region of interest and update the displacement map until the correlation threshold is exceeded.

52. The CT image analysis system, as recited in claim 42, wherein the computer is configured to determine cardiac motion by reconstructing two or more phase-specific images using the projection data set and the phase data set, and by decomposing one or more regions of interest in the two or more phase-specific images to generate wavelet coefficients of the regions of interest, and by analyzing the differences between the wavelet coefficients to generate a respective image displacement map for each pair of time-resolved images.

53. The CT image analysis system, as recited in claim 52, wherein the computer is further configured to determine whether the correlation of the wavelet coefficients of the regions of interest exceeds a correlation threshold for each image

displacement map and to subdivide the region of interest and update the displacement map until the correlation threshold is exceeded.

54. The CT image analysis system, as recited in claim 42, wherein the computer is configured to determine cardiac motion by reconstructing a time-resolved image at the phase of minimum motion using the projection data set and the phase data set, by identifying one or more view angles associated with the next adjacent phase, by forward-projecting the time-resolved image at the identified view angles to generate a set of forward projected data, by minimizing the difference between the forward projected data and the projection data set to generate a set of phase-specific displacement data, by reconstructing a phase-specific image at the next phase using the phase-specific displacement data, and by generating a set of phase-specific displacement data for the phase-specific image at the next phase and for the remaining phases of interest.

55. The CT image analysis system, as recited in claim 42, wherein the computer is configured to determine cardiac motion by identifying one or more view angles corresponding to a cardiac phase, by subtracting the projection data acquired at the next adjacent views from the projection data acquired at the view angles to generate one or more respective differential signals for the cardiac phase, and by generating motion data from the one or more respective differential signals for the remaining phases of interest.

56. A CT image analysis system, comprising:

an X-ray source configured to emit a stream of radiation while rotating slowly on a gantry;

a detector configured to detect the stream of radiation and to generate one or more signals responsive to the stream of radiation, wherein the detector comprises a plurality of detector elements;

a system controller configured to control the X-ray source and to acquire a set of projection data during one or more slow rotations or a partial rotation of the X-ray

source about a dynamic object from one or more of the detector elements via a data acquisition system;

a computer system configured to receive the set of projection data; and

means for determining the motion over time of the dynamic object; and

means for reconstructing one or more motion-corrected images.

57. The CT image analysis system as recited in claim 56, wherein the dynamic object is a heart.

58. A CT image analysis system, comprising:

an X-ray source configured to emit a stream of radiation while rotating slowly on a gantry;

a detector configured to detect the stream of radiation and to generate one or more signals responsive to the stream of radiation, wherein the detector comprises a plurality of detector elements;

a system controller configured to control the X-ray source and to acquire a set of projection data during one or more slow rotations or a partial rotation of the X-ray source about a heart from one or more of the detector elements via a data acquisition system;

a computer system configured to receive the set of projection data; and

means for acquiring a phase data set for the heart;

means for determining cardiac motion of the heart;

means for generating one or more motion-corrected cardiac images of the heart.